(12) UK Patent Application (19) GB (11) 2 243 041 (13) A

(43) Date of A publication 16.10.1991

(21) Application No 9008283.5

(22) Date of filing 11.04.1990

(71) Applicant
Philips Electronic And Associated Industries Limited

(Incorporated in the United Kingdom)

Philips House, 188 Tottenham Court Road, London, W1P 9LE, United Kingdom

(72) Inventor
Robert Nicholas Alcock

(74) Agent and/or Address for Service
R J Boxall
Philips Electronics, Patent and Trademark Department, Philips House, 188 Tottenham Court Road, London, W1P 9LE, United Kingdom

(51) INT CL⁵
G01S 3/28

(52) UK CL (Edition K)
H4D DFBB D507

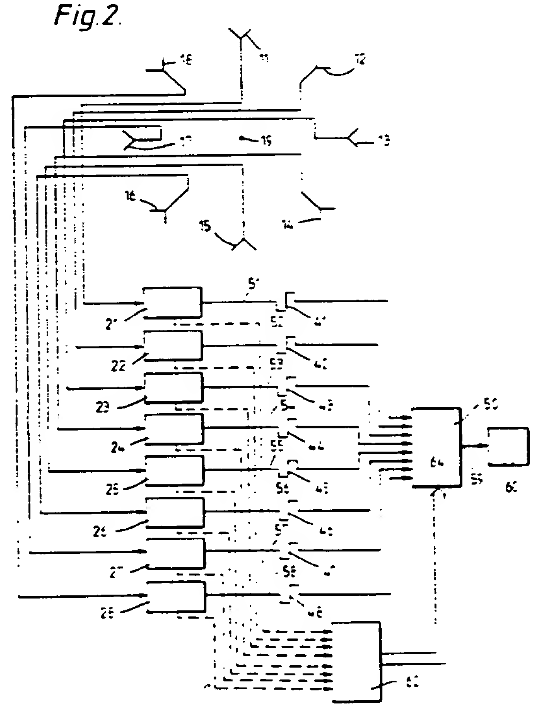
(56) Documents cited
GB 2192764 A GB 2141602 A

(58) Field of search
UK CL (Edition K) H4D DFBA DFBB DFBC DFBX DFX
INT CL⁵ G01S
Online databases: WPI

(54) Direction finding system

(57) A direction finding system comprising a circular array of directional antennas (11 to 18) arranged equally about a common axis (19). To avoid having to provide a separate omni-directional antenna to derive a signal for analysis eg frequency determination, a signal is derived from at least that one of the directional antennas receiving the strongest signal. In order to do this the r.f. signals obtained from receiver sector units (21 to 28) are examined to see which contains the strongest signal and a single-pole multiple way switch (50) is controlled to select the output of the receiver sector unit providing the strongest signal and pass the signal to an Instantaneous Frequency Measuring unit (60) for analysis. Optionally alternate directional antennas (11 to 18) are grouped together and the switch (50) is controlled to select that group containing the stronger of the combined signals for analysis.

Fig.2.



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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Fig.1.

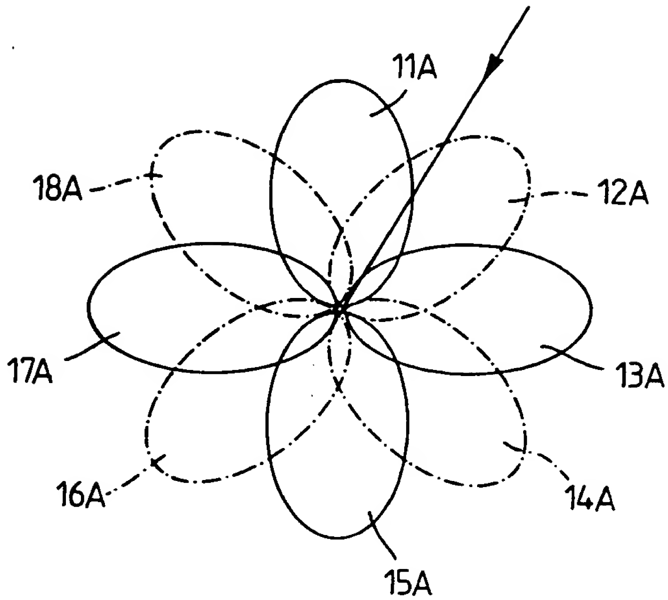


Fig.3.

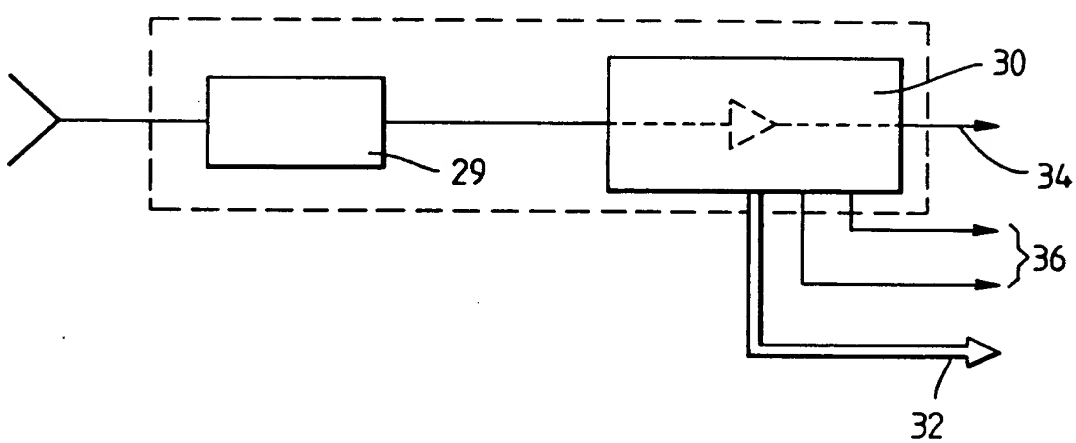
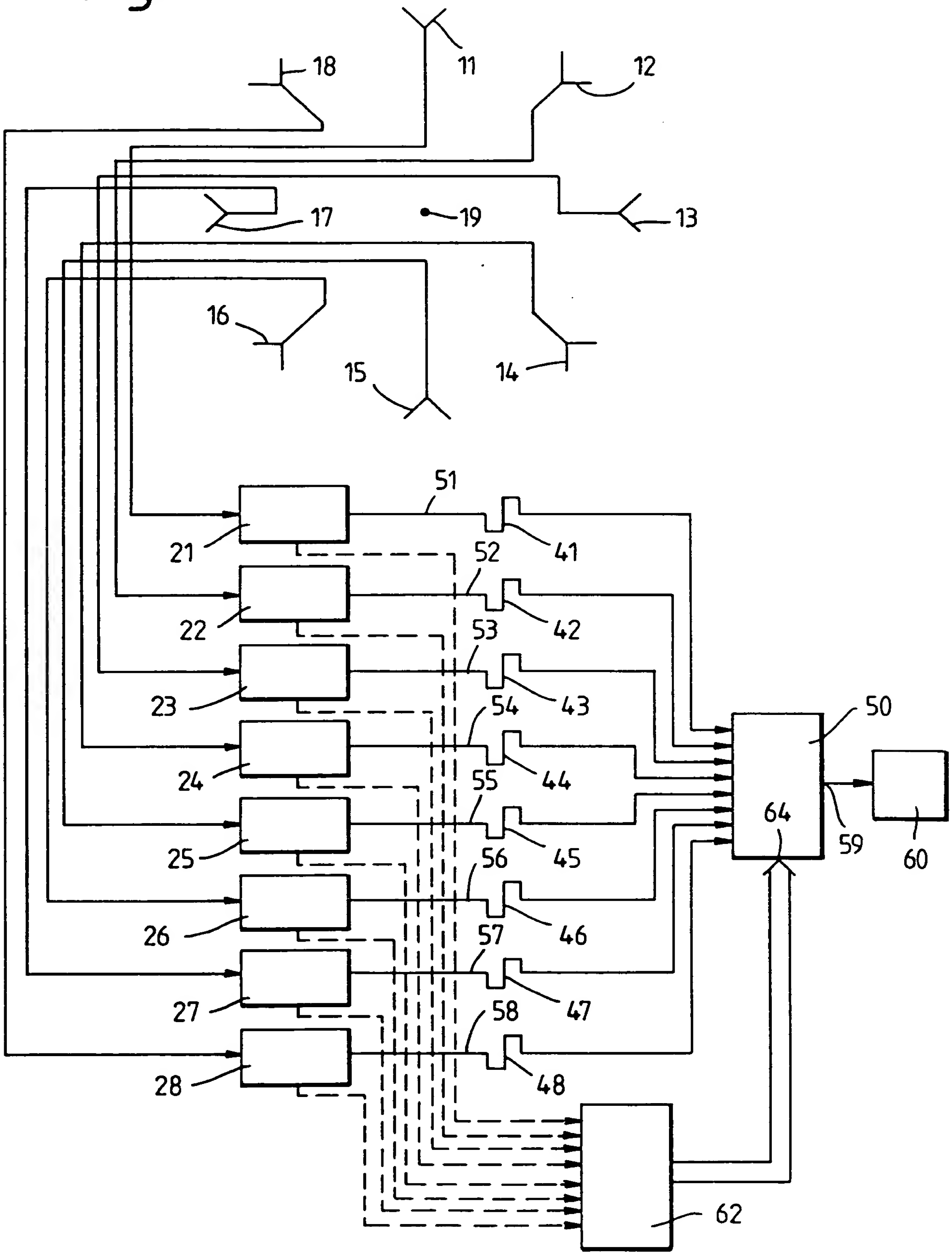


Fig.2.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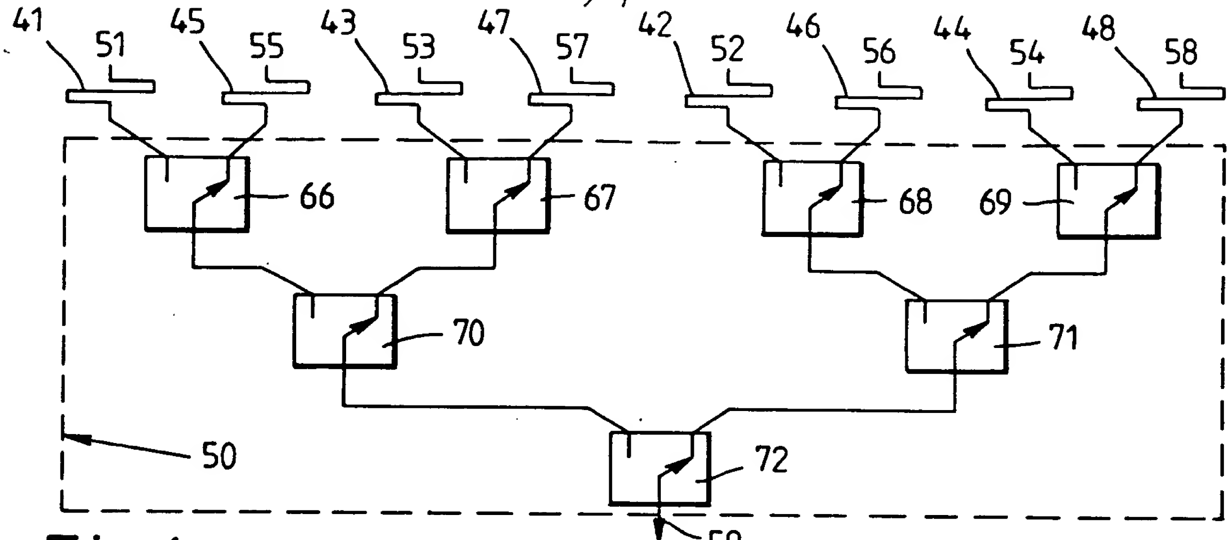


Fig.4.

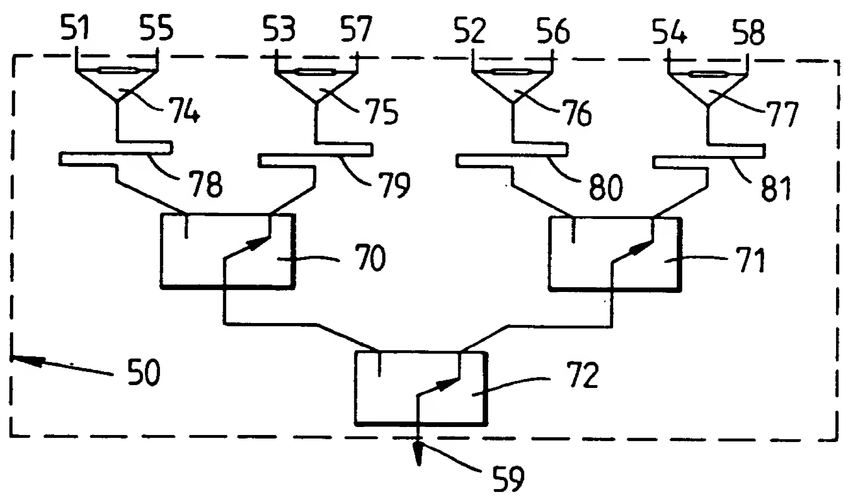


Fig.5.

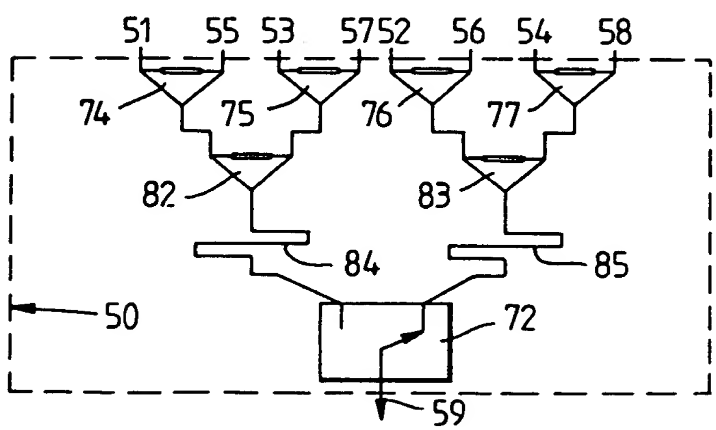


Fig.6.

Fig.7.

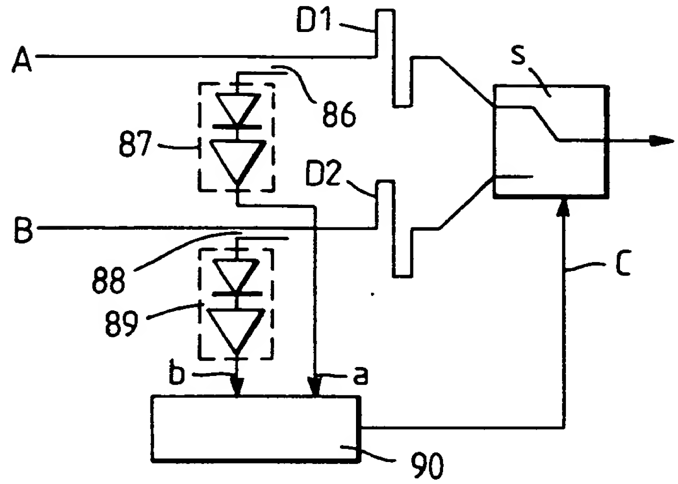


Fig.8.

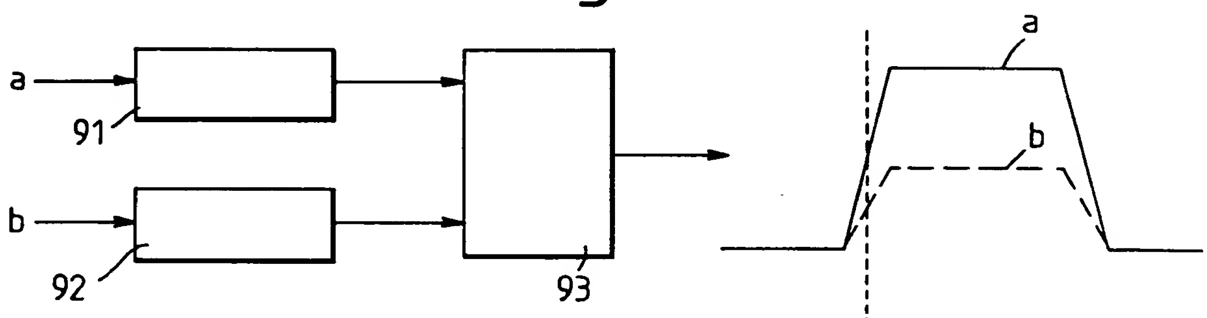


Fig.9.

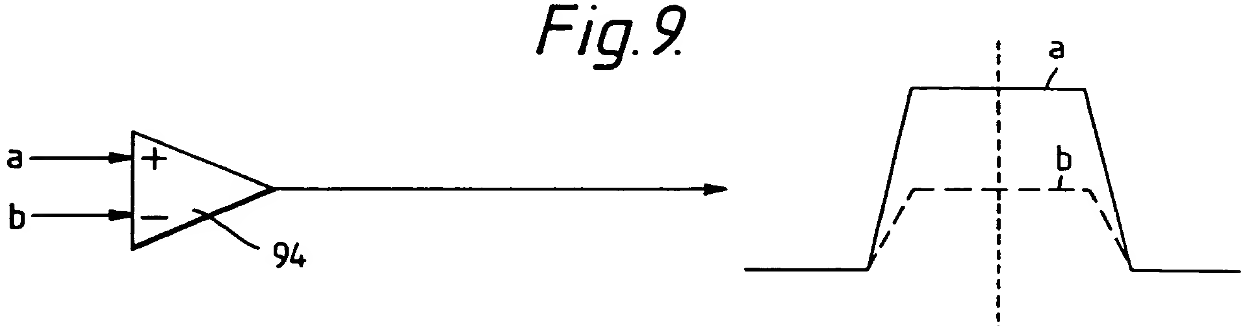
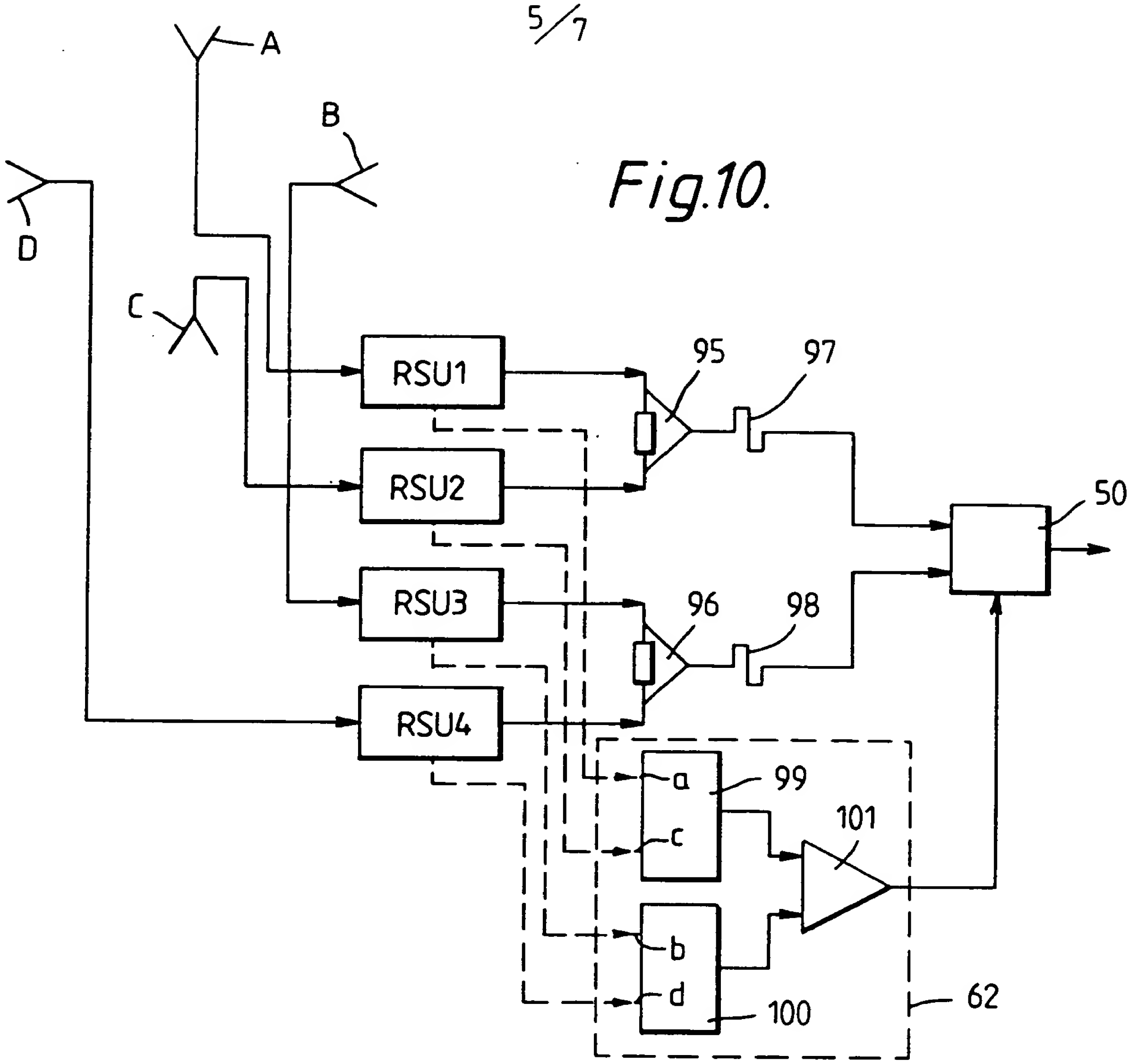


Fig.10.


A
B
C
D
RSU1
RSU2
RSU3
RSU4
95
97
96
98
50
a
c
99
101
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d
100
62

Fig.11.

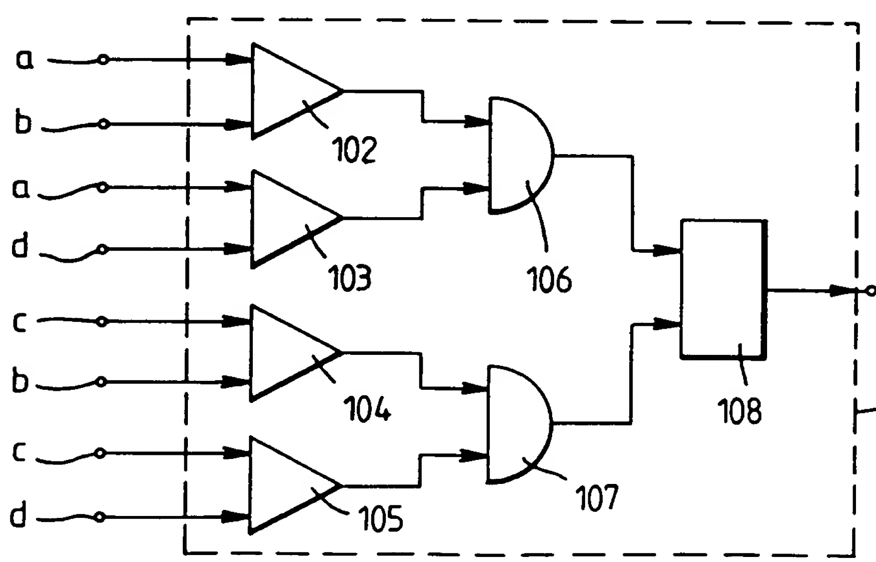

a
b
a
d
c
b
c
d
102
103
104
105
106
107
108
62

Fig.12.

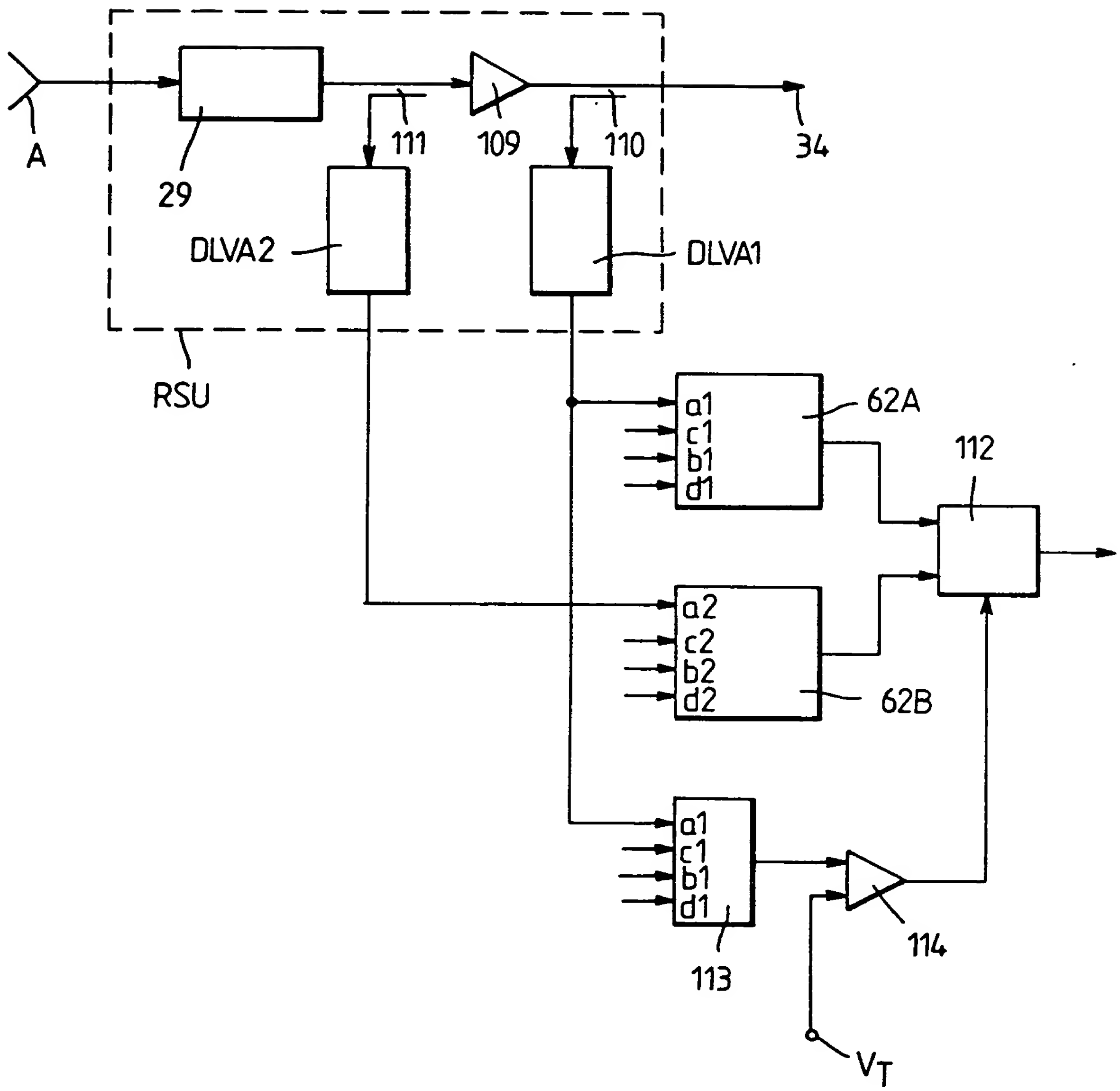
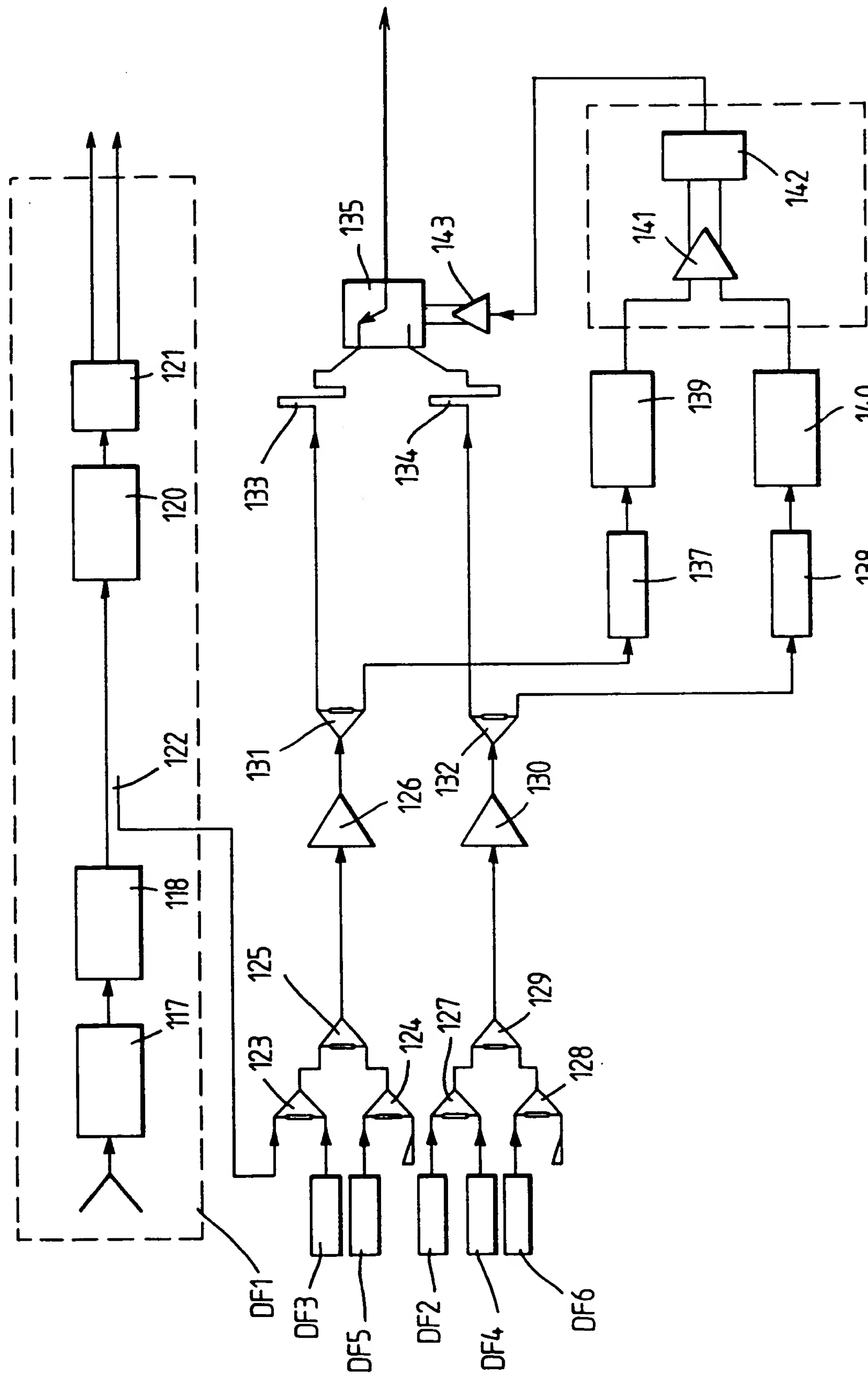

A
29
111
109
110
34
DLVA2
DLVA1
RSU
a1
c1
b1
d1
62A
112
a2
c2
b2
d2
62B
a1
c1
b1
d1
113
114
V_T

Fig.13.



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DESCRIPTION

DIRECTION FINDING SYSTEM

The present invention relates to a direction finding system.

A known direction finding system comprises a set of directional antennas with overlapping patterns which antennas are disposed in a plane and are arranged equally about a common axis perpendicular to the plane. Signals derived from the directional antennas are processed for direction finding, that is, to determine the bearing of an emitter of electromagnetic energy. In this known system a separate omnidirectional antenna is used to provide a signal for analysis, the frequency of this signal being determined by Instantaneous Frequency Measurement (IFM). When setting up such a direction finding system, particularly on a ship, it is necessary to dispose the direction finding antennas around a mast. The omnidirectional antenna is mounted on a boom at one side of the mast and the omnidirectional pattern becomes partially obscured by the mast. Accordingly, it is desired to avoid the use of an omnidirectional antenna.

According to the present invention there is provided a direction finding system comprising a set of directional antennas arranged about a common axis, receiving means coupled to each antenna for deriving an r.f. signal from a signal incident on its antenna, and selecting means coupled to the receiving means for selecting at least the largest of the r.f. signals as the signal for subsequent analysis.

The invention is based on recognition of the fact that a signal for analysis can be derived from at least one of the directional antennas thus avoiding the necessity to have a separate omnidirectional antenna. It is not possible to combine directly the amplified signals from all the directional antennas as this would result in interference nulls and loss of sensitivity when signal amplitudes in adjacent channels are

nearly equal. Figure 1 of the accompanying drawings shows typical patterns 11A to 18A for an eight antenna system. The nulls arise at bearings close to the pattern crossovers when signals in adjacent channels are in antiphase. The phase difference between signals in adjacent channels can vary rapidly with bearing over many cycles. This is because the antenna phase centre separation can be many wavelengths. Nulls are avoided if the channel containing the largest signal is switched to the IFM.

If desired, instead of selecting the largest of the r.f. signals, it is also possible to combine the r.f. signals from the non-adjacent directional antennas and select the stronger (or strongest) of the combined r.f. signals as the signal for analysis.

The selecting means may be embodied in several ways. In one embodiment it comprises a plurality of single pole, two-way switches to which pairs of r.f. signals derived from non-adjacent directional antennas are connected, the respective switches being controlled to select the larger of the signals on its inputs. In another embodiment the selecting means comprises a combination of r.f. signal combiners and single pole, two-way switches. As each of the possible embodiments also require delay devices, normally constituted by lengths of coaxial cable, to compensate for delays incurred in deriving control signals for the selecting means, the choice of a particular embodiment is a trade-off between weight and cost on the one hand and loss of sensitivity on the other hand. A selecting means constituted only by switches not only has the highest weight and cost but the largest sensitivity. The switches may comprise GaAs MMIC devices.

Processing means may be provided for deriving the control signal(s) for the selecting means. The receiving means have means for deriving a video frequency signal from the r.f. signal, which video signal is supplied to the processing means. Detector log video amplifiers (DVLA) may be used to derive the video signal, DLVAs are particularly convenient to use as they operate over dynamic ranges of up to 50dB and generate a logarithmic

video output. The log characteristic causes noise compression during a signal and this is useful for reducing uncertainty when the control signals are nearly equal in amplitude.

The present invention also provides a direction finding system comprising a set of directional antennas arranged about a common axis, receiving means coupled to each of the directional antennas, each receiving means having means for deriving an r.f. output, selecting means having inputs coupled to the r.f. output of the respective receiving means and control means for controlling the selecting means to select at least the largest one of the r.f. outputs as a signal for analysis, the control means comprising inputs for receiving signals derived from the respective r.f. signals, means for determining at least which one of the r.f. signals is the largest and means for providing a control signal to the selecting means.

The present invention will now be described, by way of example, with reference to the accompanying drawings, wherein;

Figure 1 illustrates a typical direction finding antenna pattern of eight antennas disposed equally about a common axis,

Figure 2 is a block schematic diagram of an embodiment of the invention,

Figure 3 is a block schematic diagram of a receiver sector unit used in the embodiment shown in Figure 2,

Figures 4, 5 and 6 illustrate three alternative r.f. signal selecting means which can be used in Figure 2,

Figures 7, 8 and 9 illustrate three alternative switch control methods,

Figures 10 and 11 are block schematic diagrams illustrating two methods by which switch control (or steering) signals can be derived digitally,

Figure 12 is a block schematic diagram of an arrangement by which a dynamic range extension can be obtained, and

Figure 13 is a block schematic diagram of an experimental embodiment of the system in accordance with the present

invention.

In the drawings the same reference numerals have been used to indicate the corresponding features.

Referring to Figures 1 and 2, the direction finding system comprises a circular array of eight antennas 11 to 18 disposed equally about a common axis 19. The respective antenna patterns 11A to 18A are as shown in Figure 1. The matter of nulls occurring in this pattern and the problem of combining adjacent antenna patterns has been discussed already in the preamble and accordingly it will not be repeated.

A radio receiver sector unit 21 to 28 is connected to each of the antennas 11 to 18, respectively. An example of a receiver sector unit is shown in Figure 3 and comprises a limiter/filter stage 29 connected to an antenna. The output of the stage 29 is connected to a digitising receiver 30 which is so constructed and arranged as to provide a first output 32 comprising a parallel digital representation proportional to the logarithm of the r.f. power of the signal received at the antenna, an r.f. output 34 and a video output 36 derived from the r.f. signal as will be described later. The output 32 is connected to devices known per se for deriving the direction(s) of the unknown source(s).

Reverting to Figure 2, the r.f. outputs from the receiver sector units 21 to 28 are connected by way of respective channels 51 to 58, which include time delay devices 41 to 48, to respective inputs of a selector switch 50 which is controlled to select the channel containing the largest instantaneous amplitude irrespective of the start of the activity. In this way nulls are avoided. An output 59 of the selector switch 50 is connected to an IFM 60.

The control of the selector switch 50 is effected by means of an analogue processor 62 the respective inputs of which are connected to the video signal outputs, shown in broken lines, of the receiver sector units 21 to 28. The processor 62 derives a control signal, which may be in digital form, which is supplied

to an input 64 of the selector switch 50.

The time delay introduced by the delay devices 41 to 48 is to compensate for the processing of the video signals in the analogue processor 62. The delay devices typically comprise lengths of coaxial cable.

Figure 4 shows on example of a selector switch 50 suitable for use in the embodiment shown in Figure 2. In effect the switch 50 is a single-pole 8 way switch implemented as a plurality of single-pole 2 way GaAs MMIC switches 66 to 72. Channels relating to diametrically opposite pairs of directional antennas are connected to the switches 66 to 69, that is odd-numbered channels 52,56 and 54,58 are connected respectively to the switches 68,69. The outputs of the switches 66,67, which outputs comprise the larger instantaneous amplitude of the signals at their inputs, are connected to the switch 70 whose output comprises the largest instantaneous amplitude of the signals on the odd-numbered directional antennas. In a similar manner the outputs of the switches 68,69 are connected to the inputs of the switch 71 which provides the largest instantaneous amplitude of the even-numbered directional antennas. The outputs of the switches 70,71 are applied to the inputs of the switch 72 which derives the larger of the two r.f. signals which is applied to the output 59 as the signal for analysis. In the example shown in Figure 4 there is no loss of sensitivity of the signal but it has the disadvantage that it requires 8 delay devices 41 to 48 and these are relatively large, heavy and costly.

Figures 5 and 6 show two other examples in which passive Wilkinson combiners replace some of the switches and delay lines. However, there is a trade-off between loss of sensitivity and a reduction in size, weight and cost. In Figure 5 the channels are arranged so that the signals in the diametrically opposite pairs of channels 51,55; 53,57; 52,56; and 54,58 are combined in respective Wilkinson combiners 74 to 77. The outputs of the combiners 74,75 are applied by way of respective delay

devices 78,79 to respective inputs of the switch 70. The outputs of the combiners 76,77 are applied by way of respective delay devices 80,81 to respective inputs of the switch 71. The larger of the outputs from the switches 70 and 71 is selected by the switch 72. The use of the signal combiners 74 to 77 imposes a signal to noise reduction of 3dB compared to the example shown in Figure 4.

Figure 6 represents a simplification of Figure 5 in that Wilkinson combiners 82,83 are coupled to the outputs of the pairs of combiners 74,75 and 76,77, respectively, and the outputs of the combiners 82,83 are applied by way of respective delay devices 84,85 to the inputs of the switch 72 which selects the larger of the odd- or even-numbered antenna signals. The example shown in Figure 6 imposes a 6dB reduction in the signal to noise ratio compared to Figure 4.

The analogue processor 62 (Figure 2) is configured to provide a simple means of control with minimal delay. Figures 7, 8 and 9 illustrate three examples by which switch steering signals can be derived. Figure 7 shows two r.f. channels A,B connected by respective delay devices D1,D2 to a single pole 2-way switch S having a control input C. Directional couplers 86,88 pick off a proportion of the r.f. signals in the channels A,B and supply them as video frequency signals to respective detector log video amplifiers (DVLA) 87,89 in which the signal levels are detected and amplified logarithmically. The levels of the respective signals are referenced as a and b and these signals are passed to a control device 90 which generates a logic level on the switch control input C to steer the switch so that its output is connected to the channel with the larger signal.

In Figure 8 the detected outputs a,b derived from DLVAs (not shown) are applied to respective fast-acting threshold detectors 91,92. The larger of the two signals, in the drawing it is the signal a, crosses the threshold first and a logic level is generated in a logic stage 93 to steer the switch to the channel from which it originated. The control level is latched for the

duration of the signal. This method of control is sometimes referred to as the Daffarn/Burge method. This method is unsuitable for use in applications in which one is operating on pulse-on-CW signals as the circuit would latch onto a CW signal for its duration, but not register the presence of a pulse during this period.

The example shown in Figure 9 is suitable for use with pulse-on-CW. Signals a and b detected by DLVAs (not shown) are subtracted in a wideband comparator 94 which generates a logic level which is used to control (or steer) the switch. For example when a > b, the switch S connects to channel A (Figure 7) and when b > a the switch S connects to B.

An advantage of using DLVAs to derive the video signals is that they operate over dynamic ranges of up to 50dB and generate a logarithmic video output. The log characteristic causes noise compression during a signal which is useful for reducing uncertainty when the level signals a and b are nearly equal in amplitude. Cost savings can result if the video control signals are derived from digitisers based on DLVAs.

Figure 10 illustrates a circuit in which an analogue processor 62 controls the switch 50. For simplicity, the direction finding system comprises four directional antennas A, B, C and D arranged equally about a common axis. Oppositely disposed antennas A,C are connected to respective receiver sector units RSU1 and RSU2, and oppositely disposed antennas B, D are connected to respective receiver sector units RSU3 and RSU4. R.F. outputs of RSUs 1 and 2 and r.f. outputs of RSU's 3 and 4 are combined in respective Wilkinson combiners 95, 96 and the outputs therefrom are applied to respective inputs of the switch 50 by way of delay devices 97, 98. Digitised signals a, c, b, d are derived from RSU's 1 to 4 using digitisers based on DLVAs (not shown). Signals a,c and b,d are applied to respective analogue OR gates 99,100 each of which passes the larger of the two inputs. The outputs of the OR gates 99,100 are compared in a comparator 101 which has gain and the output is applied to the

control input of the switch 50.

Figure 11 represents an analogue processor 62 comprising four comparators with gain 102, 103, 104 and 105. Digitised signals a and b are applied to the comparator 102 to obtain an output $a>b$ (or $b>a$), signals a and d are applied to the comparator 103 to obtain an output $a>d$ (or $d>a$), signals c and b are applied to the comparator 104 to obtain an output $c>b$ (or $b>c$) and finally signals c and d are applied to the comparator 105 to obtain an output $c>d$ (or $d>c$). The outputs of the comparators 102,103 and 104,105 are applied to respective AND gates 106,107 and the outputs of these AND gates are applied to OR gate 108 which passes the larger of the signals on its input as a switch control signal.

Figure 12 illustrates an arrangement which enables the dynamic range to be extended. A four directional antenna system will be described. In a simple system of the type shown in Figure 10, the RSUs each comprise a limiting filter 29 having an input coupled to the antenna and an output coupled to an input of an amplifier 109 (Figure 12) which provides the r.f. output 34. A coupler 110 couples-out part of the r.f. signal and supplies it to DLVA 1 whose output comprises a digitised video output. The video output can be processed in an analogue processor 62 of the type shown in Figure 10 or 11.

In order to extend the range, a portion of the r.f. signal from the limiter/filter stage 29 is coupled-out using a coupler 111 and supplied to another DLVA2. Assuming that the signal from antenna A is being received then the signal from DLVA1 comprises a high sensitivity signal which is applied to input a1 of analogue processor 62A. The high sensitivity signals derived from antennas C, B and D (not shown) are applied to inputs c1, b1 and d1 of the analogue processor 62A.

The respective DLVA2s provide low sensitivity signals which are applied to respective inputs a2, b2, c2 and d2 of an analogue processor 62B. The outputs from the processors 62A and 62B are applied to a level select stage 112 which provides the

switch control signal. The switch drive level is selected from the processor 62A at low level and from the processor 62B at high level. The decision on level is made by combining the high sensitivity signals a1 to d1 in an analogue OR stage 113. The output from the stage 113 is compared with a high level threshold voltage V_T in a comparator 114. If any of the signals a1 to d1 exceeds the threshold voltage V_T then the output of the processor 62B is selected, otherwise the output of the processor 62A is used as the switch control signal.

Figure 13 illustrates an experimental unit which was built around a six antenna (or port) directional finding mast head unit. The antennas and their associated direction finding units DF1 to DF6 are arranged in numerical sequence about a common axis. The direction finding unit DF1 is shown in block schematic form and comprises a bandpass filter 117 connected to the antenna and providing an output to a limiter 118. The output of the limiter 118 is connected to a DLVA 120. The logarithmic amplified video signal from the DLVA 120 is applied to a video line driver 121 and passed to a remotely located processor for digitisation and further DF processing, known per se.

An r.f. signal is derived using a 10dB directional coupler 122 inserted between the limiter 118 and the DLVA 120. R.F. signals are derived in a similar manner from the other direction finding units DF2 to DF6. The r.f. signals from the odd-numbered units are combined using Wilkinson combiners 123 to 125 and the output is amplified in a 45dB gain amplifier 126. Similarly r.f. signals from the even-numbered units are combined using Wilkinson combiners 127 to 129 and the output is amplified in a 45dB gain amplifier 130.

For ease of implementation the video control signals were derived from the respective odd and even amplified signals using Wilkinson splitters 131, 132. The combined r.f. signals from one port of each of the splitters 131, 132 are supplied by way of delay devices 133,134 to respective inputs of a single pole 2 way GaAs MMIC switch 135.

The video signals derived from the other port of each of the splitters are applied by respective 10dB pads 137,138 to DLVAs 139,140. The 10dB pads 137,138 are provided to reduce the noise on the DLVA 139,140 due to the high gain produced by the amplifiers 126 and 130. The outputs from the DLVAs are applied to a comparator 141 which subtracts one signal from the other and generates a logic level. This logic level is applied to an ECL to TTL conversion stage 142 to provide an output which, after amplification in a switch driving amplifier 143, is of a type compatible to steer the switch 135 as appropriate. The combined odd or even signal from the switch 135 is applied to a remotely located IFM (not shown). Positive feedback is applied to the comparator to provide hysteresis. This speeds up the comparator transition and acts as a threshold to reduce the switching rate on pure noise.

The illustrated experimental system operates over 6 to 18GHz. Some of the components are as follows:

Bandpass filter 117	- 2" (or 50mm) spiral bandpass filter.
DLVAs 131,132	- Quantel DLVAs (model 2700-01).
Delay devices 133,134	- 50m of coiled UT141 cable with a nominal delay of 70nS.
Switch 135	- Tachonics TCSW-0800 GAs MMIC switch.
Driver	- Impellimax GX1 TTL compatible driver.

Combining all the odd-numbered and all the even-numbered antenna signals avoids the problem of deep nulls due to phase cancellation which would occur if signals from adjacent channels were combined and which would lead to a loss of signal.

From reading the present disclosure other modifications will be apparent to persons skilled in the art. Such modifications may involve other features which are already known in the design, manufacture and use of direction finding systems and devices and component parts thereof and which may be used instead of or in addition to features already described herein. Although claims have been formulated in this application to particular combinations of features, it should be understood that the scope

of the disclosure of the present application also includes any novel combination of features disclosed herein either explicitly or implicitly or any generalisation thereof, whether or not it relates to the same invention as presently claimed in any claim and whether or not it mitigates any or all of the same technical problems as does the present invention. The applicants hereby give notice that new claims may be formulated to such features and/or combinations of such features during the prosecution of the present application or of any further application derived therefrom.

CLAIMS

1. A direction finding system comprising a set of directional antennas arranged about a common axis, receiving means coupled to each antenna for deriving an r.f. signal from a signal incident on its antenna, and selecting means coupled to the receiving means for selecting at least the largest of the r.f. signals as the signal for subsequent analysis.

2. A system as claimed in Claim 1, characterised in that the selecting means comprises means for selecting the larger of two r.f. signals derived from non-adjacent directional antennas.

3. A system as claimed in Claim 1, characterised in that the selecting means comprises first means for combining the r.f. signals derived from odd-numbered directional antennas of said set, second means for combining r.f. signals from even-numbered directional antennas of said set and switching means for selecting the larger of the combined odd- and even-numbered r.f. signals and supplying this as the r.f. signal for analysis.

4. A system as claimed in Claim 1, characterised in that the selecting means comprises n signal combiners of which a first group of n/2 signal combiners combine pairs of r.f. signals derived from odd-numbered directional antennas and a second group of r.f. signals derived from even-numbered directional antennas, and switching means for selecting the larger of the combined odd- and even- numbered r.f. signals and providing this as the signal for analysis.

5. A system as claimed in any one of Claims 1 to 4, characterised in that the selecting means includes at least one GaAs MMIC switching device.

6. A system as claimed in any one of Claims 1 to 5, characterised in that processing means are provided for producing at least one control signal for use by the selecting means when selecting the r.f. signal for analysis.

7. A system as claimed in Claim 6, characterised in that each of the receiving means has means for deriving a video frequency signal from the r.f. signal, which video signal is

supplied to the processing means.

8. A system as claimed in Claim 7, characterised in that said means for deriving a video frequency signal comprises a detector log video amplifier.

9. A system as claimed in Claim 7 or 8, characterised in that said processing means comprises at least one comparator for subtracting one signal from another and generating a logic level from which a control signal for the controlling the electing means is derived.

10. A direction finding system comprising a set of directional antennas arranged about a common axis, receiving means coupled to each of the directional antennas, each receiving means having means for deriving an r.f. output, selecting means having inputs coupled to the r.f. output of the respective receiving means and control means for controlling the selecting means to select at least the largest one of the r.f. outputs as a signal for analysis, the control means comprising inputs for receiving signals derived from the respective r.f. signals, means for determining at least which one of the r.f. signals is the largest and means for providing a control signal to the selecting means.

11. A direction finding system constructed and arranged to operate substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

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